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Indian Standard

METHODS OF MEASUREMENT OF AIRBORNE NOISE EMITTED BY ROTATING ELECTRICAL MACHINERY

PART 1 ENGINEERING METHOD FOR FREE-FIELD CONDITIONS OVER A REFLECTING PLANE

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Indian Standard

METHODS OF MEASUREMENT OF AIRBORNE NOISE EMITTED BY ROTATING ELECTRICAL MACHINERY

PART 1 ENGINEERING METHOD FOR FREE-FIELD CONDITIONS OVER A REFLECTING PLANE

NATIONAL FOREWORD

This Indian Standard (Part 1) which is identical with ISO 1680/1 : 1986 'Acoustics — Test code for the measurement of airborne noise emitted by rotating electrical machinery — Part 1 : Engineering method for free-field conditions over a reflecting plane' issued by the International Organization for Standardization (ISO), was adopted by the Bureau of Indian Standards on the recommendation of the Acoustics Sectional Committee (LTD 5) and approval of the Electronics and Telecommunication Division Council.

The text of ISO standard has been approved as suitable for publication as Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following :

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'; and

b) Comma (,) has been used as decimal marker while in Indian Standards, the current practice is to use point (.) as the decimal marker.

CROSS REFERENCES

International Standard	*Indian Standard*	*Degree of Correspondence*
ISO 354 : 1985 Acoustics — Measurement of sound absorption in a reverberation room	IS 8225 : 1987 Measurement of sound absorption in a reverberation room (*first revision*)	Identical
ISO 1680/2 : 1986 Acoustics — Test code for the measurement of airborne noise emitted by rotating electrical machinery — Part 2 : Survey method	IS 12998 (Part 2) : 1990 Methods of measurement of airborne noise emitted by rotating electrical machinery : Part 2 Survey method	Identical
IEC Pub 225 : 1966 Octave, half-octave and third-octave band filters intended for the analysis of sound and vibrations	IS 6964 : 1973 Octave, half-octave and third-octave band filters for analysis of sound and vibrations	Technically equivalent
IEC Pub 651 : 1979 Sound level meters	IS 9779 : 1981 Specification for sound level meters	Technically equivalent
IEC Pub 34-1 : 1983 Rotating electrical machines — Part 1 : Rating and performance	IS 12824 : 1989 Type of duty and classes of rating assigned to rotating electrical machines	Technically equivalent
	IS 12802 : 1989 Temperature rise measurement of rotating electrical machines	Technically equivalent
	IS 4722 : 1968 Rotating electrical machines	Technically equivalent

The Technical Committee responsible for the preparation of this standard has reviewed the provisions of the following International Publications and has decided that they are acceptable for use in conjunction with this standard :

ISO 266 : 1975 Acoustics — Preferred frequencies for measurements

ISO 2204 : 1979 Acoustics — Guide to International Standards on its measurement of airborne acoustical noise and evaluation of its effects on human beings

ISO 3740 : 1980 Acoustics — Determination of sound power levels of noise sources — Guidelines for the use of basic standards and for the preparation of noise test codes

ISO 3741 : 1988 Acoustics — Determination of sound power levels of noise sources — Precision methods for broad-band sources in reverberation rooms

ISO 3742 : 1988 Acoustics — Determination of sound power levels of noise sources — Precision methods for discrete frequency and narrow-band sources in reverberation rooms

ISO 3744 : 1981 Acoustics — Determination of sound power levels of noise sources — Engineering methods for free-field conditions over a reflecting plane

ISO 3745 : 1977 Acoustics — Determination of sound power levels of noise sources — Engineering methods for anechoic and semianechoic rooms

ISO 6926 : 1979 Acoustics — Determination of sound power levels of noise sources — Characterization and calibration of reference sound sources

0 Introduction

This part of ISO 1680 is based on ISO 3744 and has been drafted in accordance with ISO 3740.

The main purpose of this part of ISO 1680 is to specify a clearly defined measurement method for rotating electrical machines operating under steady-state conditions, the results of which can be expressed in sound power levels so that all machines tested using this code can be directly compared. Other methods, such as the precision methods of ISO 3741, 3742 and 3745, may also be used for determining sound power levels if the installation and operating conditions of this part of ISO 1680 are used.

1 Scope and field of application

1.1 General

This part of ISO 1680 specifies, in accordance with ISO 2204, an engineering method (grade 2) for measuring the sound pressure levels on a rectangular parallelepiped surface enveloping the machine and for calculating the sound power level produced by the machine. It outlines the procedures which may be used to evaluate the test environment and specifies the characteristics of suitable measuring instruments. A method is given for determining the A-weighted sound power level and, if required, octave or one-third octave band sound power levels of the machine from the mean of the sound pressure levels measured on the rectangular parallelepiped surface.

This part of ISO 1680 applies to the measurement of airborne noise from rotating electrical machines, such as motors and generators (d.c. and a.c. machines) without any limitation on the output or voltage, when fitted with their normal auxiliaries. It applies to rotating electrical machines with any linear dimension (length, width or height) not exceeding 15 m.

This part of ISO 1680 applies to measurements carried out in environmental conditions that meet the criteria given in clause 4 and annex A (environmental correction $K \leq 2$ dB, correction for background noise ≤ 1 dB). If these criteria are not met, standard deviations of the test results may be greater than those given in table 1, i.e. the engineering grade of accuracy may not be achieved. The method given in ISO 1680/2 shall then be used, which will result in A-weighted sound power levels of lower accuracy. In this case, no reference shall be made to this part of ISO 1680.

1.2 Measurement uncertainty

Measurements carried out in conformity with this part of ISO 1680 usually result in standard deviations which are equal to or less than those given in table 1. The standard deviations given in table 1 reflect the cumulative effects of all causes of measurement uncertainty, excluding variations in the sound power level of the machine from test to test. For a machine which emits noise with a relatively "flat" spectrum in the 100 to 10 000 Hz frequency range, the A-weighted sound power level is determined with a standard deviation of approximately 2 dB. For outdoor measurements, the standard deviation in the octave band centred on 63 Hz will be approximately 5 dB.

NOTE — The standard deviations in table 1 include the effects of allowable variations in the positioning of the measurement positions and in the selection of the stipulated measurement surface.

Table 1 — Uncertainty in determining sound power levels for engineering measurements indoors or outdoors

Octave band centre frequencies Hz	One-third octave band centre frequencies Hz	Standard deviation of mean value dB
125	100 to 160	3,0
250 to 500	200 to 630	2,0
1 000 to 4 000	800 to 5 000	1,5
8 000	6 300 to 10 000	2,5

2 References

ISO 266, *Acoustics — Preferred frequencies for measurements.*

ISO 354, *Acoustics — Measurement of sound absorption in a reverberation room.*

ISO 1680/2, *Acoustics — Test code for the measurement of airborne noise emitted by rotating electrical machinery — Part 2: Survey method.*

ISO 2204, *Acoustics — Guide to International Standards on the measurement of airborne acoustical noise and evaluation of its effects on human beings.*

ISO 3740, *Acoustics — Determination of sound power levels of noise sources — Guidelines for the use of basic standards and for the preparation of noise test codes.*

ISO 3741, *Acoustics — Determination of sound power levels of noise sources — Precision methods for broad-band sources in reverberation rooms.*

ISO 3742, *Acoustics — Determination of sound power levels of noise sources — Precision methods for discrete-frequency and narrow-band sources in reverberation rooms.*

ISO 3744, *Acoustics — Determination of sound power levels of noise sources — Engineering methods for free-field conditions over a reflecting plane.*

ISO 3745, *Acoustics — Determination of sound power levels of noise sources — Precision methods for anechoic and semi-anechoic rooms.*

ISO 6926, *Acoustics — Determination of sound power levels of noise sources — Characterization and calibration of reference sound sources.*[1]

IEC Publication 34-1, *Rotating electrical machines — Part 1: Rating and performance.*

IEC Publication 225, *Octave, half-octave and third-octave band filters intended for the analysis of sounds and vibrations.*

IEC Publication 651, *Sound level meters.*

3 Definitions

For the purposes of this part of ISO 1680, the following definitions apply.

3.1 free field: A sound field in a homogeneous, isotropic medium free of boundaries. In practice, it is a field in which the effects of the boundaries are negligible over the frequency range of interest.

3.2 free field over a reflecting plane: A sound field in the presence of a reflecting plane on which the source is located.

3.3 anechoic room: A test room the surfaces of which absorb essentially all the incident sound energy over the frequency range of interest, thereby affording free-field conditions over the measurement surface.

3.4 semi-anechoic room: A test room with a hard reflecting floor the other surfaces of which absorb essentially all the incident sound energy over the frequency range of interest, thereby affording free-field conditions above a reflecting plane.

3.5 sound pressure level, L_p, in decibels: Twenty times the logarithm to the base 10 of the ratio of the sound pressure to the reference sound pressure. The weighting network or the width of the frequency band and its centre frequency used shall be indicated: for example, A-weighted sound pressure level, L_{pA}, octave band sound pressure level, one-third octave band sound pressure level, etc. The reference sound pressure is 20 µPa.

3.6 surface sound pressure: The sound pressure averaged in time on a mean-square basis and also averaged over the measurement surface using the averaging procedures specified in 8.1 and corrected for the effects of background noise and the influence of reflected sound at the measurement surface.

3.7 surface sound pressure level, $\overline{L_{pf}}$, in decibels: Ten times the logarithm to the base 10 of the ratio of the square of the surface sound pressure to the square of the reference sound pressure.

3.8 sound power level, L_W, in decibels: Ten times the logarithm to the base 10 of the ratio of a given sound power to the reference sound power. The weighting network or the width of the frequency band used shall be indicated: for example, A-weighted sound power level, L_{WA}, octave band sound power level, one-third octave band sound power level, etc. The reference sound power is 1 pW ($= 10^{-12}$ W).

NOTE — The surface sound pressure level is numerically different from the sound power level and its use in lieu of the sound power level is not correct because the size of the measurement surface is not covered by this quantity.

3.9 frequency range of interest: For general purposes, the frequency range of interest includes the octave bands with centre frequencies between 125 and 8 000 Hz or the one-third octave bands with centre frequencies between 100 and 10 000 Hz. Any band may be excluded in which the level is more than 40 dB below the highest band pressure level. For special purposes, the frequency range of interest may be extended at either end, provided that the test environment and instrument accuracy are satisfactory for use over the extended frequency range. For sources which radiate predominantly high (or low) frequency sound, the frequency range of interest may be limited in order to optimize the test facility and procedures.

3.10 measurement surface: A hypothetical surface of area S enveloping the source on which the measurement positions are located and which terminates on the reflecting plane.

3.11 reference box: A hypothetical surface which is the smallest rectangular parallelepiped that just encloses the source and terminates on the reflecting plane.

3.12 measurement distance: The minimum distance from the reference box to the measurement surface.

3.13 background noise: The sound pressure level at each microphone position with the source inoperative.

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[1] At present at the stage of draft.

4 Acoustic environment

4.1 General

The test environments that are suitable for measurements in accordance with this part of ISO 1680 include the following:

a) a room which provides a free field over a reflecting plane;

b) a flat outdoor area that meets the requirements of 4.2 and annex A;

c) a room in which the contributions of the reverberant field to the sound pressures on the measurement surface are small compared with those of the direct field of the source.

Conditions described under c) above are met in very large rooms as well as in smaller rooms with sufficient sound-absorptive materials on their walls and ceilings.

4.2 Criteria for adequacy of the test environment

Annex A describes a procedure for determining whether or not a test environment is adequate for measurements in accordance with this part of ISO 1680. Test environments which are suitable for engineering measurements permit the sound power level to be determined with an uncertainty that does not exceed the values given in table 1.

Ideally, the test environments are free from reflecting objects other than a reflecting plane so that the source radiates into a free field over a reflecting plane. Annex A describes procedures for determining the magnitude of the environmental correction (if any) to account for departures of the test environment from the ideal condition.

To comply with this part of ISO 1680, the environmental correction K shall not exceed 2 dB.

If it is necessary to make measurements in spaces which do not meet the criteria of annex A, standard deviations of the test results may be greater than those given in table 1. In those cases, ISO 1680/2 shall be used. (See clause 0.)

4.3 Criterion for background noise

At each microphone position, the sound pressure level of the background noise shall be at least 6 dB, and preferably more than 10 dB, below the sound pressure level to be measured in each frequency band within the frequency range of interest.

Background noise less than 6 dB below the sound pressure levels to be measured is too high for the purposes of this part of ISO 1680. Under such circumstances, the survey method of ISO 1680/2 shall be used. (See clause 0.)

4.4 Wind

The wind velocity existing at the test site or caused by the machine under test shall be less than 6 m/s. A windscreen should be used for wind velocities above 1 m/s to ensure that the level of the background noise (caused by the cumulative effect of the wind and other background noise sources) is at least 6 dB, and preferably more than 10 dB, below the level with the source operating. The appropriate instructions provided by the microphone manufacturer shall be followed.

5 Instrumentation

5.1 General

The instrumentation shall be designed to measure the mean square value of the A-weighted sound pressure level and the octave or one-third octave band levels, averaged over time and over the measurement surface. Surface averaging is usually carried out by measuring the time-averaged sound pressure levels with a prescribed time constant for a fixed number of microphone positions (7.2) and computing the average value in accordance with 8.2.

The instrumentation used can perform the required time-averaging in one of two different ways:

a) By continuous averaging of the squared signal using RC-smoothing with a time constant τ_A. Such continuous averaging provides only an approximation of the true time-average, and it places restrictions on the "settling" and observation times (see 7.3.3).

NOTE — An example of an instrument using such averaging is a sound level meter fulfilling at least the requirements for a type 1 instrument in accordance with IEC Publication 651 with the time weighting "S"

b) By integrating the squared signal over a fixed time-interval τ_D. This integration may be performed by either digital or analogue means.

Examples of suitable instrumentation systems are given in ISO 3744.

5.2 The microphone and its associated cable

A condenser microphone, or the equivalent in accuracy, stability and frequency response, shall be used. The microphone shall have a flat frequency response, over the frequency range of interest, for the angle of incidence specified by the manufacturer.

NOTE — This requirement is met by a microphone of a standardized sound level meter fulfilling at least the requirements for a type 1 instrument in accordance with IEC Publication 651 and calibrated for free-field measurements.

The microphone and its associated cable shall be chosen so that their sensitivity does not change over the temperature range encountered in the measurement. If the microphone is moved, care shall be exercised to avoid noise of acoustical origin (for example, noise from wind, gears, mechanical moving parts) or electrical noise (for example, noise from flexing cables or sliding contacts) that could interfere with the measurements.

5.3 Frequency response of the instrumentation system

The frequency response of the instrumentation system for the angle of incidence specified by the manufacturer shall be flat over the frequency range of interest within the tolerances given for a type 1 instrument in IEC Publication 651.

5.4 Weighting network and frequency analyser

An A-weighting network complying with the tolerance requirements of IEC Publication 651 and, if required, an octave band or one-third octave band filter set fulfilling the requirements of IEC Publication 225 shall be used. The centre frequencies of the frequency bands shall correspond to those of ISO 266.

5.5 Calibration

Before and after each series of measurements, an acoustical calibrator with an accuracy ± 0,5 dB shall be applied to the microphone to check the calibration of the entire measuring system at one or more frequencies over the frequency range of interest. The calibrator shall be checked annually to verify that its acoustical output has not changed. In addition, an acoustical and an electrical calibration of the instrumentation system over the entire frequency range of interest shall be carried out at intervals of not more than 2 years.

6 Installation and operation of the machine

6.1 Machine mounting

If practicable, the machine should be mounted in the same way as it would be for normal usage. Care should be taken to minimize the transmission and the radiation of structure-borne noise from all mounting elements including the foundation. Usually, this minimizing can be achieved by resilient mounting for smaller machines. Larger machines can usually only be tested under rigid mounting conditions.

6.1.1 Resilient mounting

The natural frequency of the support system and the machine under test shall be lower than a quarter of the frequency corresponding to the lowest rotational speed of the machine.

The effective mass of the resilient support shall not be greater than 1/10 of that of the machine under test.

6.1.2 Rigid mounting

The machines shall be rigidly mounted to a surface with dimensions adequate for the machine type (for example by foot or flange fixed in accordance with the manufacturer's specifications). The machine shall not be subject to additional mounting stresses from incorrect shimming.

The mass of the support shall be at least twice that of the machine under test.

6.2 Operation of machine during test

The machine shall operate at no load, at rated voltage(s) and speed(s), and with the corresponding excitation(s) (see IEC Publication 34-1).

For a.c. machines, the sinusoidality of the supply voltage and the degree of unbalance of the supply voltage system shall comply with the same limits that are specified in IEC Publication 34-1.

Synchronous machines shall be run with the excitation current which permits the rated voltage at no load.

For machines not suitable for no-load operation, e.g. machines with the behaviour of series-wound motors, the operating conditions shall be agreed upon and stated in the test report.

A method for estimating the difference in the level of the noise from a machine between no-load operating conditions and rated load or any other specified load is given in annex C.

6.3 Auxiliary equipment and coupled machines

All auxiliary equipment (loading machines, gears, transformers, external cooling systems) and coupled machines which are necessary for the operation of the machine under test, but which do not form an integral part of the machine, shall not significantly affect the noise measurement (see 8.1). If they do, they should be shielded acoustically or located outside the test environment.

7 Sound pressure levels on the measurement surface

7.1 Reference box and measurement surfaces

In order to facilitate the positioning of the microphone positions, a hypothetical reference box is defined (see 3.11). When defining the dimensions of this reference box, elements protruding from the machine which are unlikely to be major radiators of sound energy may be disregarded.

The microphone positions lie on the measurement surface (see 3.10).

For rotating electrical machines, regardless of their size, the measurement surface shape is a rectangular parallelepiped (see figures 2 to 4) the sides of which are parallel to the sides of the reference box and spaced out at a distance d (measurement distance) from the reference box.

The measurement distance, d, shall be at least 0,25 m. Distances larger than 1 m may be excluded by the environmental requirements given in this part of ISO 1680 (see 4.2, 4.3 and annex A). The preferred measurement distance is 1 m.

The area S of the measurement surface is given by the equation

$$S = 4\,(ab + bc + ca)$$

where, in accordance with figures 2, 3 or 4,

$a = 0{,}5\, l_1 + d$;

$b = 0{,}5\, l_2 + d$;

$c = l_3 + d$;

l_1, l_2 and l_3 are the dimensions of the reference box;

d is the measurement distance, normally 1 m.

7.2 Microphone array

7.2.1 Complete measurement position array

From figure 1, the principle of how to construct the measurement array for different sizes of reference box can be derived.

Each side of the measurement surface shall be treated separately. If the length or width of the side of the measurement surface under consideration exceeds 3*d*, this side is divided into a minimum number of partial areas so that their lengths and widths do not exceed 3*d* (see figure 1).

To comply with the engineering method of this part of ISO 1680, measurement positions shall be placed at the middle and the corners of each partial area, except at those corners which lie in the reflecting plane. The corner positions of a partial area are identical with the corner positions of the neighbouring partial areas.[1)]

The resulting complete measurement array is shown in figures 2 to 4 for different sizes of the reference box.

Neighbouring measurement positions may be connected to achieve continuous paths along which the microphone is carried continuously with constant velocity (see figures 2 to 4).

NOTE — For the survey method complying with ISO 1680/2, only the positions in the middle of the partial areas (or the relevant paths through these positions) are used.

7.2.2 Simplified measurement position array

The arrangement of the measurement positions given in figures 1 to 4 may, especially for large machines, be simplified, if, for that type of machine, it can be shown, with the help of preliminary investigations on some machines of that type, that the sound field is adequately uniform and that measurements lead to values of sound power level deviating by no more than 1 dB from those determined with a complete arrangement of measurement positions.

For sources that produce a symmetrical radiation pattern, it may be sufficient to distribute the measurement positions over only a portion of the measurement surface. This is acceptable if, for that type of machine, it can be shown, with the help of preliminary investigations on some machines of that type, that the measurements lead to values of sound power level deviating by no more than 1 dB from those determined with a complete arrangement of measurement positions.

7.3 Conditions of measurement

7.3.1 General

Environmental conditions may have an adverse effect on the microphone used for the measurements. Such conditions (for example, due to strong electric or magnetic fields, wind, impingement of air discharged from the machine under test, high or low temperatures) shall be minimized by proper selection or positioning of the microphone. The microphone shall always be directed in such a way that the angle of incidence of the sound waves is that for which the microphone is calibrated.

The observer shall not stand between the microphone and the source under test.

The measurements shall be carried out once the machine under test is operating under steady-state conditions.

The sound pressure level shall be observed over a typical period of operation of the source. Readings of the sound pressure level (corresponding to the level of the mean-square sound pressure) shall be taken at each measurement point with A-weighting and, if required, for each frequency band within the frequency range of interest.

The following data shall be obtained:

a) the A-weighted sound pressure levels and, if required, the band pressure levels during operation of the machine under test;

b) the A-weighted sound pressure levels and, if required, the band pressure levels produced by the background noise.

For the frequency bands centred on or below 160 Hz, the observation period shall be at least 30 s. For A-weighted sound pressure levels and for the frequency bands centred on or above 200 Hz, the observation period shall be at least 10 s.

7.3.2 Measurements with a sound level meter

If the indicating meter of a sound level meter is used, the time weighting "S" shall be used. If the fluctuations of the indicating pointer on the sound level meter are less than ± 3 dB using the time weighting "S", the noise is considered to be steady for the purposes of this part of ISO 1680 and the level is taken to be the average of the maximum and minimum levels during the period of observation. If the meter fluctuations during the period of observation are greater than ± 3 dB, the noise is considered to be non-steady and one of the instrumentation systems described in ISO 3744 shall be used.

7.3.3 Measurements with RC-smoothing or integration systems

If RC-smoothing is used, the time-constant τ_A should be long enough to obtain an estimate of the r.m.s. level during the period of observation with an accuracy of ± 0,5 dB.

If true integration is used, it is necessary for the integration time to be equal to the period of observation.

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1) The array is in complete accordance with ISO 3744 for small machines (see figure 3) and, in principle, in accordance with ISO 3744 for large machines, taking into account the sound field structure of rotating electrical machinery.

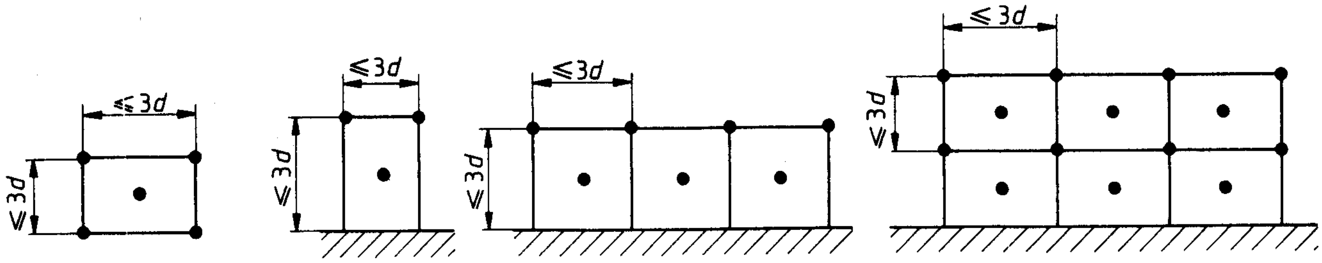
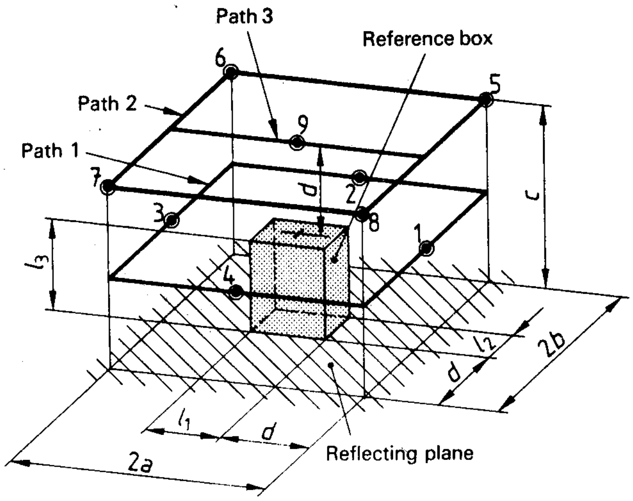
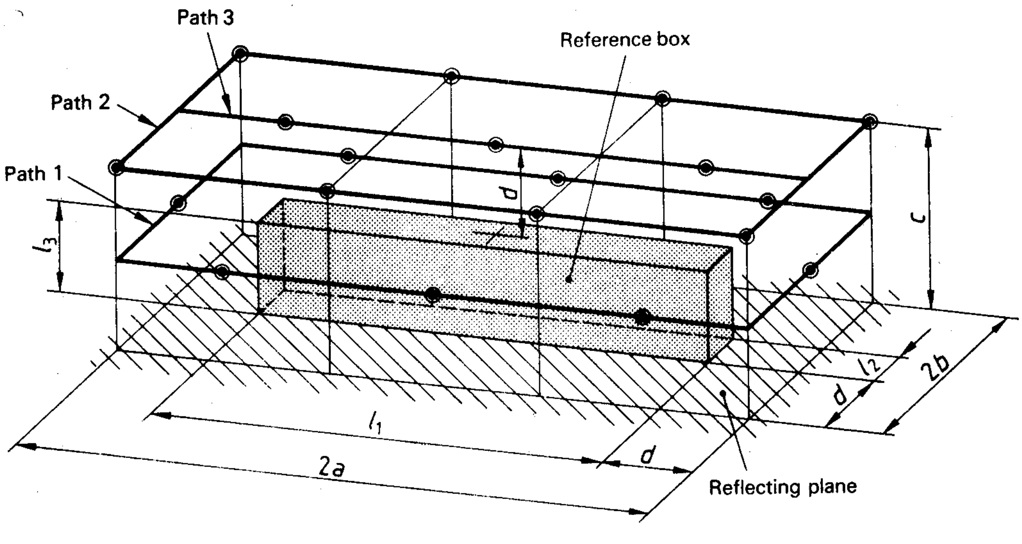


Figure 1 — Procedure for fixing the measurement positions where a side of the measurement surface exceeds 3*d*



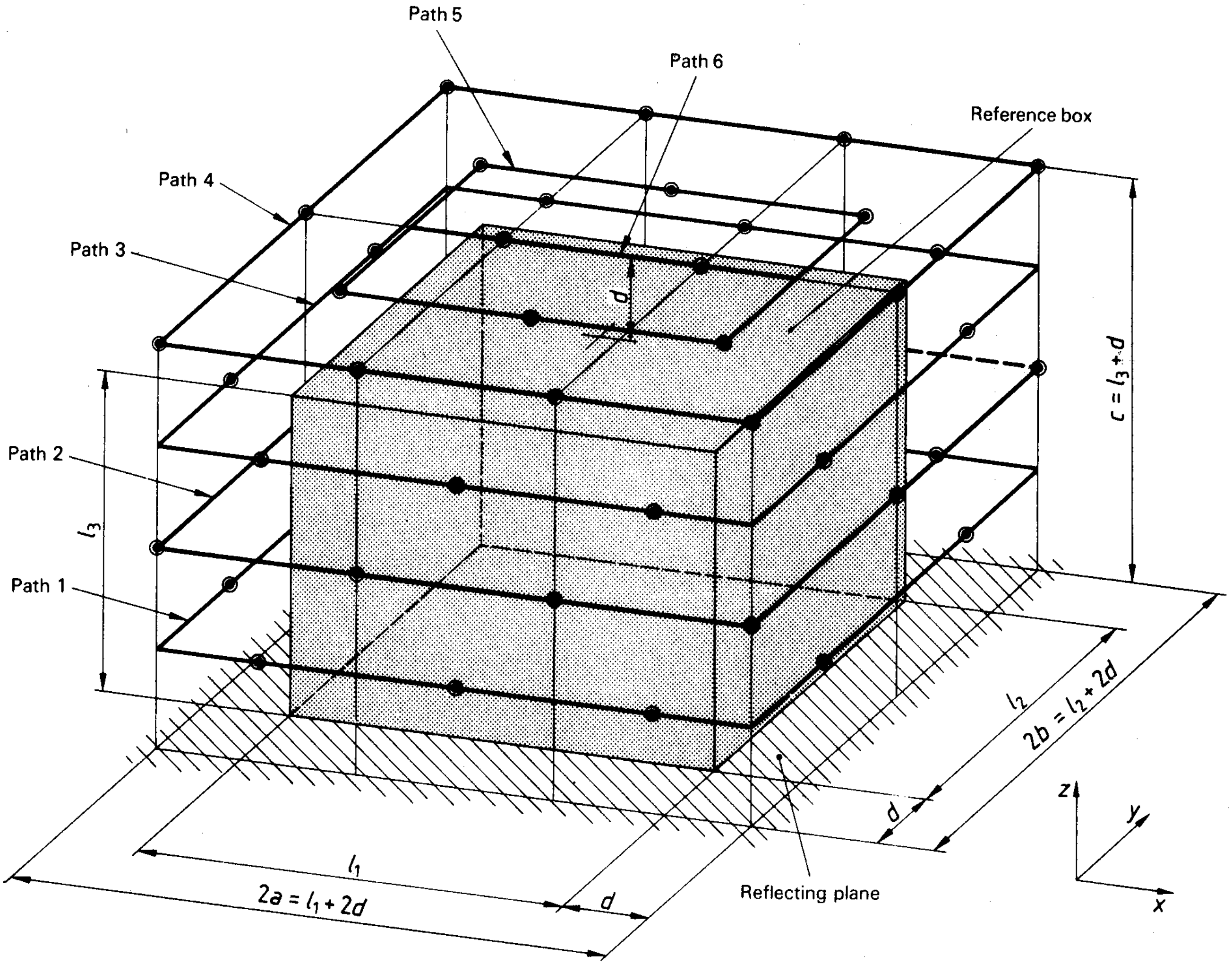
NOTE — For the survey method of ISO 1680/2, only paths 1 and 3 (positions 1, 2, 3, 4, 9) are used.

Figure 2 — Example of a measurement surface and measurement positions (paths) for a small machine
($l_1 < d$, $l_2 < d$, $l_3 < 2d$, where d is the measurement distance, normally 1 m)



NOTE — For the survey method of ISO 1680/2, only paths 1 and 3 with their positions are used.

Figure 3 — Example of a measurement surface and measurement positions (paths) for a long machine
($4d < l_1 \leqslant 7d$, $l_2 \leqslant d$, $l_3 < 2d$)



NOTE — For the survey method of ISO 1680/2, only paths 1, 3 and 5 with their positions are used.

Figure 4 — Example of a measurement surface and measurement positions (paths) for a large machine
($4d < l_1 \leqslant 7d$, $d < l_2 \leqslant 4d$, $2d < l_3 \leqslant 5d$)

8 Calculation of surface sound pressure level and sound power level

8.1 Corrections for background noise

The measured sound pressure levels shall be corrected for background noise in accordance with table 2.

Table 2 — Corrections for background sound pressure levels

Difference Δ between sound pressure level measured with machine operating and background sound pressure level alone dB	Corrections to be subtracted from sound pressure level measured with machine operating to obtain sound pressure level due to machine alone dB
<6	Measurements invalid
6	1,0
7	1,0
8	1,0
9	0,5
10	0,5
>10	0

8.2 Calculation of sound pressure level averaged over the measurement surface

For the A-weighted sound pressure level and the level in each frequency band of interest, an average sound pressure level over the measurement surface, $\overline{L_p}$, is calculated from the relevant measured sound pressure levels L_{pi} (after corrections for background noise are applied in accordance with 8.1) by using the following equation:

$$\overline{L_p} = 10 \lg \left[\frac{1}{N} \sum_{i=1}^{N} 10^{0,1 L_{pi}} \right] \qquad \ldots (1)$$

where

$\overline{L_p}$ is the sound pressure level averaged over the measurement surface, in decibels; reference: 20 µPa;

L_{pi} is the A-weighted or band pressure level resulting from the i^{th} measurement, in decibels; reference: 20 µPa;

N is the total number of measurement positions.

8.3 Calculation of surface sound pressure level

The surface sound pressure level, $\overline{L_{pf}}$, shall be obtained by correcting the value of $\overline{L_p}$ for reflected sound to approximate the average value of the sound pressure level which would be obtained under free-field conditions, by using the following equation:

$$\overline{L_{pf}} = \overline{L_p} - K \qquad \ldots (2)$$

where

$\overline{L_{pf}}$ is the surface sound pressure level, in decibels; reference: 20 µPa;

K is the mean value of the environmental correction over the measurement surface, in decibels.

For the purposes of this part of ISO 1680, the maximum acceptable range of the environmental correction, K, is −2 dB to +2 dB.

NOTE — The environmental correction, K, accounts for the influence of a non-ideal environment (for example, the presence of reflected sound). It ranges typically from −2 dB (for measurements outdoors with absorbing ground) to +10 dB (for measurements indoors in highly reverberant rooms). The procedures given in annex A are used to calculate the value of the environmental correction.

8.4 Calculation of sound power level

The sound power level characterizing the noise emitted by the source shall be calculated from the following equation:

$$L_W = \overline{L_{pf}} + 10 \lg \left(\frac{S}{S_0} \right) \qquad \ldots (3)$$

where

L_W is the A-weighted or band sound power level of the source, in decibels; reference: 1 pW;

$\overline{L_{pf}}$ is the surface sound pressure level determined in accordance with 8.3, in decibels; reference: 20 µPa;

S is the area of the measurement surface, in square metres (see 7.1);

$S_0 = 1\ \text{m}^2$.

If only band sound power levels are determined, the A-weighted sound power level may be determined in accordance with annex B.

9 Information to be recorded

The following information shall be compiled and recorded for all measurements carried out in accordance with the requirements of this part of ISO 1680.

9.1 Machine under test

a) Description of the machine under test (including its dimensions).

b) Operating conditions.

c) Mounting conditions.

d) If the machine has multiple noise sources, a description of source(s) in operation during the measurements.

9.2 Acoustic environment

a) Description of the test environment;

1) if indoors, description of physical treatment of walls, ceiling and floor, sketch showing the location of machine under test and room contents;

2) if outdoors, sketch showing the location of machine under test with respect to surrounding terrain, including physical description of test environment.

b) Acoustical qualification of the test environment in accordance with annex A.

c) Air temperature in degrees Celsius, barometric pressure in pascals, and relative humidity.

d) Wind velocity and direction.

e) Sound power level of the reference sound source, if used.

9.3 Instrumentation

a) Equipment used for the measurements, including name, type, serial number and manufacturer.

b) Bandwidth of frequency analyser.

c) Frequency response of instrumentation system.

d) Method used for checking the calibration of the microphones and other system components; the date and place of calibration shall be given.

e) Characteristics of windscreen (if used).

9.4 Acoustical data

a) The measurement distance, the location and direction of microphone positions.

b) The area S of the measurement surface.

c) The corrections, in decibels, if any, applied in each frequency band for the frequency response of the microphone, frequency response of the filter in the passband, background noise, etc.

d) The environmental correction, K, calculated in accordance with one of the procedures given in annex A.

e) The surface sound pressure level, $\overline{L_{pf}}$, in decibels, calculated from the measured A-weighted sound pressure levels or from the sound pressure levels in each frequency band of interest; reference: 20 µPa.

f) The sound power level, L_W, in decibels, calculated from the A-weighted surface sound pressure level and, if required, from the surface sound pressure levels for all frequency bands used; reference: 1 pW.

g) If required, difference Δ of the levels of the noise between no-load and on-load operation, A-weighted and, if required, in frequency bands.

h) Remarks on subjective impression of noise (audible discrete tones, impulsive character, spectral content, temporal characteristics, etc.).

i) The date when the measurements were carried out.

10 Information to be reported

The test report shall contain the statement that the sound power levels have been obtained in full conformity with the procedures of this part of ISO 1680.

The following information shall be reported:

a) a description of the machine under test;

b) the operating conditions;

c) the A-weighted sound power level, L_{WA}, in decibels, and, if required, sound power levels in frequency bands; reference: 1 pW;

d) if required, difference Δ of the levels of the noise between no-load and on-load operation, A-weighted and, if required, in frequency bands;

e) the date when the measurements were carried out.

Annex A

Qualification procedures for the acoustic environment

(This annex forms an integral part of the standard.)

A.1 General

An environment providing a free field over a reflecting plane shall be used for measurements made in accordance with this part of ISO 1680. This environment is provided by a semi-anechoic room, an outdoor space or an ordinary room if the requirements given in this annex are satisfied.

The test room shall be large enough and, if possible, free from reflecting objects with the exception of the reflecting plane. The test room shall provide a measurement surface that lies

a) inside a sound field that is free of undesired sound reflections from the room boundaries;

b) outside the near field of the sound source under test.

The environmental correction, K, in equation (2) (see 8.3) accounts for the influence of undesired sound reflections from room boundaries and/or reflecting objects near the sound source under test.

For open test sites which consist of a hard, flat ground surface, such as asphalt or concrete, and with no sound-reflecting obstacles within a distance from the source equal to three times the greatest distance from the source centre to the lower measurement points, it may be assumed that the environmental correction, K, is less than or equal to 0,5 dB and is, therefore, negligible.

NOTE — An obstacle in the proximity of the source may be considered to be sound-reflecting if its width (for example, diameter of a pole or supporting member) exceeds 1/10 of the distance from the reference box.

The environmental correction, K, may also be assumed to be negligible for indoor environments which are laboratory anechoic rooms meeting the requirements of ISO 3745.

The evaluation of environmental influences is performed by selecting one of two alternative procedures used to determine the magnitude of the environmental correction, K. These procedures are used to determine if any undesired environmental influences are present and to qualify a given measurement surface for an actual source under test in accordance with this part of ISO 1680.

The first qualification procedure (Absolute comparison test, see clause A.3) is carried out with a reference sound source. The second qualification procedure (Reverberation test, see clause A.4) may be used if the source under test cannot be moved and if its dimensions are large. This procedure requires measurements of reverberation time.

The free-field qualification on a given measurement surface is satisfied by a given test room if the ratio of the sound absorption A of the room to the area S of the measurement surface is sufficiently large. In general, ratios $A/S > 10$ require no environmental corrections. For ratios A/S between 10 and 6, an environmental correction, K, can be determined in accordance with the procedures given in this annex. In this case, K is usually smaller than 2 dB. For ratios $A/S < 6$, the room correction factor K may exceed 2 dB and cause greater uncertainty for the sound power level determinations than those given in table 1. In such cases, a smaller measurement surface, a better environment or a measurement in accordance with the survey method (see ISO 1680/2) should be chosen. The reflecting plane should satisfy the requirements given in A.2.1. For outdoor measurements, additional precautions given in A.2.3 should be considered.

A.2 Environmental conditions

A.2.1 Properties of reflecting plane

Measurements may be made in one of the following environments:

- over a reflecting plane outdoors;
- in a test room with one reflecting surface; or
- in a test room with sound absorptive surfaces in which a reflecting plane is present.

NOTE — Particularly when the reflecting surface is not a ground plane or is not an integral part of a test room surface, care should be exercised to ensure that the plane does not radiate any appreciable sound due to vibrations.

A.2.1.1 Shape and size

The reflecting plane shall not be smaller than the projection of the measurement surface on the plane.

A.2.1.2 Acoustic absorption coefficient

The acoustic absorption coefficient of the reflecting plane, measured in accordance with ISO 354, should preferably be less than 0,1 over the frequency range of interest. This requirement is usually fulfilled when measurements are made over concrete, sealed, asphalt or stone surfaces. For indoor measurements, wooden and tiled floors are permitted.

A.2.2 Reflecting objects

No reflecting objects which are not part of the source under test shall be located inside the measurement surface.

A.2.3 Precautions for outdoor measurements

Care should be taken to minimize the effects of adverse meteorological conditions (for example, temperature, humidity, wind, precipitation) on the sound propagation over the frequency range of interest or on the background noise during the course of the measurements.

If a windscreen is used to shield the microphone from the effects of wind, proper corrections of the measured sound pressure levels shall be made.

A.3 Absolute comparison test to determine K

A.3.1 Procedure

A reference sound source with characteristics that meet the requirements of ISO 6926 shall be mounted in the test environment in essentially the same position as that of the source under test. The sound power level of the reference sound source is determined in accordance with the procedures of clauses 7 and 8 without the environmental correction K (i.e. K is initially assumed equal to zero). The same measurement surface is used as during the measurements of the source under test. The environmental correction K is given by

$$K = L_W - L_{Wr}$$

where

L_W is the calculated A-weighted or band power level of the reference sound source using procedures of clauses 7 and 8 [with $K = 0$ in equation (2)], in decibels; reference: 1pW;

L_{Wr} is the name plate A-weighted or band power level of the reference sound source, in decibels; reference: 1 pW.

A.3.2 Locations of reference sound source in test environment

A.3.2.1 Source can be removed from test site

The reference sound source shall be located on the reflecting plane, independent of the height of the machine. One single location is sufficient, even when very large machines are to be tested, provided the ratio of the length of the machine under test to its width is not greater than 2. If the ratio is greater than 2, the reference sound shall be operated on the floor at four points. Assuming the projection of the machine under test on the floor to be approximately rectangular in shape, the four points are located at the middle points of the sides of the rectangle. To obtain L_W, the surface sound pressure level, $\overline{L_{pf}}$ shall be calculated with the reference sound source located at each of the four points on the floor. At each point on the measurement surface, the sound pressure level shall be averaged for the four source locations on a mean-square basis, i.e. using equation (1) in 8.2.

A.3.2.2 Source cannot be removed from test site

The reference sound source shall be located on the upper surface of the machine which should preferably be acoustically reflective. This method should not be applied if the machine has highly absorptive surfaces (for example, textile machines), In this case, the procedure of clause A.4 should be followed.

A.3.3 Qualification requirements

For the measurement surface in a given test environment to be satisfactory for measurements in accordance with the requirements of this part of ISO 1680, the environmental correction, K, shall be numerically less than or equal to 2 dB. If the environmental correction, K, exceeds 2 dB, either a smaller measurement surface or a better test environment is required.

When the necessary changes have been made, the test procedure to determine K shall be repeated.

A.4 Reverberation test to determine K

A.4.1 Test procedure

This test procedure is applicable to rooms the maximum dimension of which does not exceed significantly its minimum dimension.

The environmental correction, K, is obtained from the expression

$$K = 10 \lg \left(1 + \frac{4}{A/S}\right)$$

The value of K may be obtained from figure 5 by entering the abscissa with the appropriate value of A/S. The area S of the measurement surface is calculated in accordance with the requirements given in 7.1.

The total sound absorption area, A, of the test room is determined from measurements of the reverberation time of the test room in octave bands for the entire frequency range of interest (see ISO 354).

The value of A is then

$$A = 0{,}16\,(V/T)$$

where

V is the volume of the test room, in cubic metres;

T is the reverberation time of the test room in octave band, in seconds.

A.4.2 Qualification requirements

For the measurement surface in a test room to be satisfactory for measurements in accordance with the requirements of this part of ISO 1680, the ratio A to S should exceed 6, that is $A/S > 6$.

If this requirement cannot be satisfied, a new measurement surface shall be chosen. The new measurement surface should have a smaller total area, but still lie outside the near field. Alternatively, the ratio A/S may be increased by introducing additional sound-absorptive materials into the test room and then redetermining the value of the ratio A/S under the new conditions.

If the requirements of this clause cannot be satisfied for any measurement surface which lies outside the near field of the source under test, the particular test environment chosen cannot be used for measurements on the source under test in accordance with the requirements of this part of ISO 1680. A new test environment shall be selected or it shall be assumed that the uncertainties may exceed the values given in table 1.

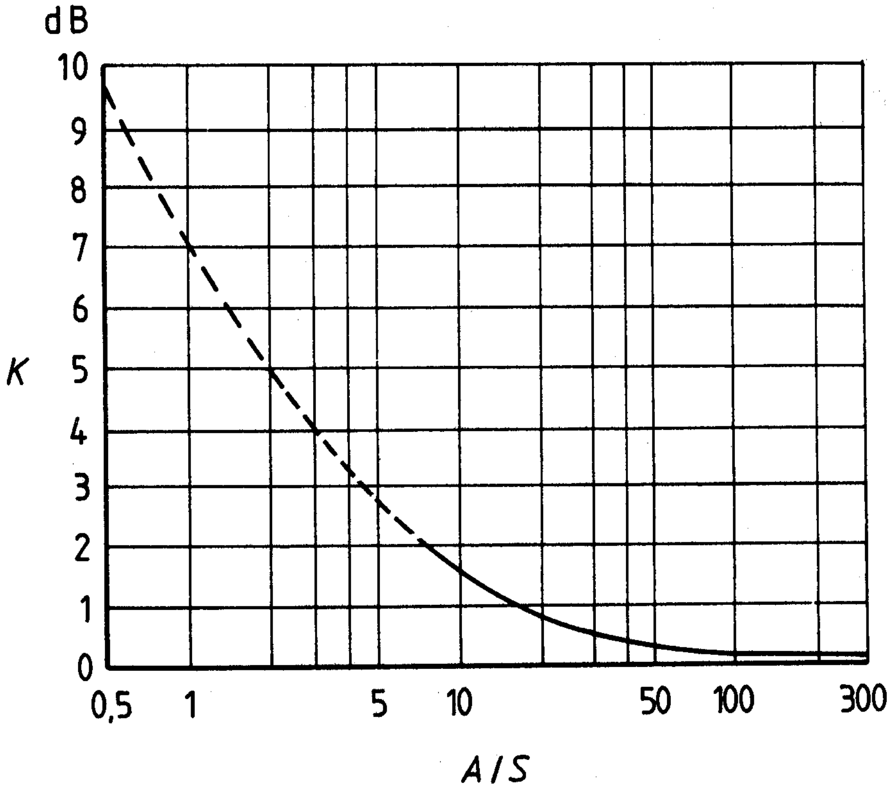


Figure 5 — Environmental correction, *K*, in decibels

Annex B

Procedures for calculating A-weighted sound power level from octave or one-third octave band power levels

(This annex forms an integral part of the standard.)

B.1 Calculate the A-weighted sound power level, L_{WA}, in decibels (reference: 1 pW) from the formula:

$$L_{WA} = 10 \lg \sum_{J=1}^{J_{\max}} 10^{0,1[(L_W)_J + C_J]}$$

where $(L_W)_J$ is the level in the J^{th} octave or third-octave band.

B.2 For calculations with octave band data, $J_{\max} = 7$ and C_J is given in table 3.

Table 3 — Parameters for calculating A-weighted sound power level from octave band power levels

J	Octave band centre frequency Hz	C_J dB
1	125	− 16,1
2	250	− 8,6
3	500	− 3,2
4	1 000	0
5	2 000	+ 1,2
6	4 000	+ 1,0
7	8 000	− 1,1

B.3 For calculations with one-third octave band data, $J_{\max} = 21$ and C_J is given in table 4.

Table 4 — Parameters for calculating A-weighted sound power level from one-third octave band power levels

J	One-third octave band centre frequency Hz	C_J dB
1	100	− 19,1
2	125	− 16,1
3	160	− 13,4
4	200	− 10,9
5	250	− 8,6
6	315	− 6,6
7	400	− 4,8
8	500	− 3,2
9	630	− 1,9
10	800	− 0,8
11	1 000	0
12	1 250	0,6
13	1 600	1,0
14	2 000	1,2
15	2 500	1,3
16	3 150	1,2
17	4 000	1,0
18	5 000	0,5
19	6 300	− 0,1
20	8 000	− 1,1
21	10 000	− 2,5

Annex C

Method for estimating the difference in noise level between no-load and on-load operations

NOTE — This annex does not form an integral part of the standard insofar as this estimation method cannot be classified as being of engineering grade accuracy.

C.1 General

This annex describes a method which can be used to obtain an estimate of the difference in the levels of the noise between no-load and on-load operations.

This method should be used by agreement between the manufacturer and the purchaser if it is expected that there will be a significant difference in the noise emission of the machine between no load and the rated or any other specified load.

C.2 Installation and operation of machines

C.2.1 Machine mounting

See 6.1.

C.2.2 Operation of machine during test

The machine shall be operated, coupled to its load machine, at its rated voltage(s), speed(s) and corresponding excitation(s) with no load applied to the load machine and then with the rated or other specified load applied.

If possible, the machine under test should be mechanically uncoupled from an electrical load machine so that background noise measurements can be made with the load machine operating as a motor at rated voltage(s), speed(s) and corresponding excitation(s). There will be many occasions where it is neither possible to uncouple the load machine mechanically nor to operate the load machine as a motor. Under these conditions, measurements should be made at no load and at the rated or other specified load only.

C.3 Measurement array

The measurement array used shall be the same as that for the no-load test (see clause 7), but the distance of the microphone from the reference surface of the machine shall be 0,15 m. If it is not possible to have a particular measurement location, due to the presence of, for example, a bearing pedestal, the measurement position should be moved just enough to overcome the obstruction.

NOTE — As the method described in this annex aims at the determination of a level difference Δ (see clause C.5), the measurement array is treated as being sufficient also for the small measurement distance of 0,15 m, which is taken to minimize the environmental influences.

C.4 Measurement of sound pressure levels

At each microphone position on the measurement surface, the A-weighted sound pressure level shall be measured with the machine operating at no load and then at the rated or other specified load. The measurements shall be carried out after the machine has reached a steady temperature.

If possible, measurements should be made at each microphone position, after the machine has been switched off and mechanically uncoupled from the load machine and with the load machine operating as a motor at its rated voltage(s), speed(s) and corresponding excitation(s).

The sound pressure levels measured with the test machine operating at no load and then on full load are corrected for background noise (see 8.1) and are then used to determine the average sound pressure levels over the measurement surface in accordance with 8.2. The background noise will include the no-load noise of the loading machine if it was possible to run it disconnected from the machine under test.

C.5 Estimation of differences in level of the noise between no-load and on-load operations

The difference Δ between the on-load and no-load sound pressure levels is obtained as follows:

$$\Delta = \overline{L_{pAr}} - \overline{L_{pAR}}$$

where

$\overline{L_{pAr}}$ is the A-weighted sound pressure level over the measurement surface according to clause C.3 in on-load conditions (for calculation, see 8.1 and 8.2);

$\overline{L_{pAR}}$ is the A-weighted sound pressure level over the measurement surface according to clause C.3 at no load.

NOTE — If it has not been possible to measure the level of the background noise contributed by the loading machine, the difference Δ has to be calculated from the mean values of the A-weighted sound pressure levels as measured, without correction for that background noise; this case should be indicated in the test report.

An estimate of the on-load A-weighted sound power level of the machine may be obtained by adding the difference Δ to the value of A-weighted sound power level obtained from no-load measurements in accordance with clauses 7 and 8. This estimate being derived from measurements at 0,15 m distance may lead to an uncertainty greater than indicated in table 1. Therefore, this estimate of the on-load A-weighted sound power level cannot be classified as being of engineering grade accuracy.

The difference Δ may also be determined in frequency bands, if required.

C.6 Information to be recorded

The information listed in clause 9 should be recorded for all tests carried out in accordance with this annex.

C.7 Information to be reported

The information listed in clause 10 should be reported together with the calculated difference Δ.

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